2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33316

An Evolving Face-to-Face Freshman Experience Course During a Pandemic

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An Evolving Face-to-Face Freshman Experience Course During a Pandemic

Abstract

A traditional freshman experience course transitioned to a hybrid face-to-face version in the Fall 2020 quarter because of the COVID-19 pandemic. The course features a virtual lecture each week and ten separate hands-on face-to-face activities that required different modes of instruction and involved different social distancing protocols. Furthermore, the course was required to provide virtual accommodation for those students who chose not to return to campus or were placed in quarantine during some part of the quarter. This paper describes the challenges and risks of conducting this course during a pandemic, covers the solutions implemented for each of the activities, and provides assessment data on what worked and what can be improved in the future. With the reopening of college campuses just beginning, other engineering programs with freshman experience courses would certainly benefit from these lessons learned.

Introduction

With the full effect of the COVID-19 pandemic reaching the United States in March 2020, almost all colleges and universities went exclusively to virtual on-line instruction during the spring semesters and quarters. In the fall, according to the College Crisis Initiative study at Davidson College of 3000 schools, as colleges opened back up 4% were fully in person, 23% primarily in person, 21% were hybrid, 34% primarily on-line, 10% fully on-line and 8% either undetermined or other [1]. Many colleges selectively reopened specific classes for face-to-face instruction with varying degrees of success and some had to quickly shut down again. Many of these courses were upper division laboratory or activity classes. There were fewer which opened such courses for incoming freshman classes.

This paper covers the rapid transition of a traditional freshman experience to a hybrid face-to-face course in the Fall 2020 quarter. The course features a virtual lecture each week and ten separate hands-on activities that required different modes of instruction and involved different social distancing protocols. Furthermore, the course was required to provide virtual accommodation for those students who chose not to return to campus or were placed in quarantine during some part of the quarter. For some activities, the students away from campus could participate fully in the activities; while for others, they were only able to watch the face-to-face students perform the activity while still completing the assignment. A few activities lent themselves to be conducted virtually for everyone. For others, the best solution was a synchronous Zoom session simultaneously projected on a classroom screen using a participant's smartphone to capture the activity being conducted live. For other activities, an asynchronous solution provided a richer experience for the students using PowerPointShow, video footages, and Screencast-O-Matic editing. The hands-on activities included arches and catenaries, concrete anchor bolts, timber connections, welding and testing steel, creating and testing trusses in the digital fabrication lab, drainage patterns, failure case studies, wiring electrical circuits, and a design-bid-build competition using K'nex toys.

This paper describes the challenges and risks of conducting this course during a pandemic, covers the solutions implemented for all of the activities, and provides assessment data on what worked and what can be improved in the future. With the reopening of college campuses just beginning, other engineering programs with freshman experience courses would certainly benefit from these lessons learned.

ARCE 106 Introduction to Building Systems

ARCE 106 "Introduction to Building Systems" was taught for the first time in the Fall Quarter 2015 in the Architectural Engineering (ARCE) department at California Polytechnic State University in San Luis Obispo. It is offered only in the fall quarter and the entire ARCE freshman class is block scheduled into it. It has been team-taught in a face-to-face format by the same two faculty members for the past five years. In the Fall 2020 quarter, the COVID-19 pandemic forced the course to change to a hybrid model that aligned with university restrictions and protocols and sufficiently protected the faculty and students involved in this course.

The course objectives for ARCE 106 are:

- Identify and illustrate building systems in our day-to-day lives and explain the functions they serve.
- Articulate the key components of different building systems with their role towards a successful building in an architectural engineering context.
- Describe how specific buildings integrate various building systems together successfully.
- Compare/Contrast when to use different structural systems and different structural materials under various scenarios.
- Describe the roles/responsibilities of the various professions involved in the creation of a building.
- Develop a sense of community with your fellow ARCE students.

The course was designed to engage freshmen in the profession of engineering, create hands-on learn-by-doing experiences, and hopefully reduce the attrition rate early in the program. The two-unit course meets twice a week. The first meeting is a 50-minute Tuesday morning lecture with the entire class in attendance – typically between 80-100 students. The second meeting is a two-hour hands-on activity where the class is subdivided into four separate activity sections and the enrollment in each section is capped at 24 students. The four activities occur on Wednesday and Thursday and complement the lecture. Estes and Lawson [2] described the development of this course in detail.

The Pandemic Conditions

During the Spring quarter of 2020, Cal Poly switched entirely to a virtual environment between the winter and spring quarters on very short notice and continued this mode of instruction through the summer school courses. For the Fall quarter, the California State University system mandated virtual instruction for all lecture courses but allowed for exceptions for laboratory experiences that required face-to-face interaction for the pedagogy to be effective. The Cal Poly

guidance became that laboratory and activity sections had the option to conduct face-to-face instruction for the fall quarter under the following conditions:

1. The university needed to approve the classroom and the social distancing precautions in advance. Table 1 shows the various social distancing protocols in this course as dictated by the specific activities and location of an event.
2. The department chose to offer a virtual alternative for any student that could not come or did not feel comfortable coming to class.
3. Any faculty member could change the course to virtual instruction for the same reason.

Table 1: Categories of Social Distancing used in ARCE 106

Category	Description of Precautions Needed for this Social Distancing Category
A	All virtual – no social distancing required
B	Outdoor environment – wearing masks; students passed university's daily digital screening tool as reported on their smartphones
C	Indoor lab with sufficient ventilation to simulate outdoor environment– same as B and lab must have sanitation stations and appropriate signage
D	Indoor classroom where students will remain six feet apart – same as C; classrooms wiped down between usages; windows and doors open to provide maximum ventilation
E	Indoor classroom where students will be less than six feet apart – same as D; students wearing masks and face shields

The Lecture

Usual format: The weekly lecture is held in person in a large lecture hall with all students in attendance. The presentation mode is PowerPoint with occasional videos or demonstrations included. Each of the ten weeks is devoted to a specific topic that are in order: Introduction, Structural Systems, Reinforced Concrete, Timber, Steel, Foundations and Site Civil, Architectural Coverings and Cladding, Electrical and Lighting, Mechanical and Plumbing, and Ethics and Professional Responsibility. The instructor grade (10%) is determined by lecture attendance as determined by participation in small group activities. Students are provided with a copy of the slides on Canvas (the course management system) after the lecture. A weekly homework assignment is distributed during the lecture and on Canvas. Homework from the previous week is submitted in paper copy at the beginning of class.

COVID format: The weekly lecture is conducted on Zoom with all students attending remotely. The content did not change at all. The instructor grade (10%) was based on attendance as evidenced by answering poll questions. There was no social distancing required (i.e., Category A Table 1). The homework assignment was distributed electronically on Canvas and submitted by students in the same manner. There was little to no change in the quality of educational experience for the student relative to the usual format.

Disadvantages: It was more difficult for the instructors to get to know the students and for the students to interact with each other. The Zoom screen allows the instructor to only see a quarter of the class at a time. The critical thinking exercises were individual exercises through poll questions rather than group activities.

Advantages: The Zoom sessions were recorded so that students who missed the lecture could view it later on Canvas. The university did not have to schedule one of the scarce large lecture halls for this course. It was easier for any guest speakers to attend the class virtually.

The Activities

The two-hour hands-on weekly activities were more complicated because most of the instruction was face-to-face with social distancing for those students who could attend and with a virtual accommodation for those who could not. Each activity required a different solution.

Activity #1: Introductory Presentations and Learning Style Assessment

Usual format: Each student created a three-minute, three-slide PowerPoint presentation. The textbook for this course is Building Construction Illustrated [3]. The first slide required the student to peruse the textbook, find a topic of interest, and present it. The second slide was on a personal interest or hobby and the third slide was to find and describe an iconic structure that was personally inspirational. The assignment is introduced in the Tuesday lecture and the student has only 24 hours to prepare the presentation. Each activity meets in a classroom and the students come to the front of the class in turn to make their individual oral presentations in conjunction with their projected slide images. To prevent problems with loading flash-drives into a common computer, the students submit their presentation slides through Canvas and the instructor reviews them all in advance. The submissions are graded on timely submission, completion of the three slides, and length of presentation being at least one minute and not more than three.

The second part of the activity is introducing Felder's Learning Style Model [4], [5] and completing his learning style inventory survey. The results of the survey provide each student with rating on a scale of 1 to 11 regarding their preference for sensory versus intuitive, visual versus verbal, active versus reflective, and sequential versus global learning situations. Using slides from the ASCE ExCEEd Teaching Workshop [6], the instructor explains what the learning style dimensions mean and provides insights as to how students can use this information to assist in their own learning. The survey sheets are collected, the data are assembled and the composite results for the entire course are shown at a later date.

COVID format: This was one of two activities in the course that were conducted entirely virtually. The content was identical and the activity was conducted for each of the four sections on a Zoom meeting where each student shared their screen and made their presentations as their names were called. The grading rubric was the same and the instructor needed less preparation time because the students were running their presentations on their own computers, so there were no file compatibility or software problems. The activity lost a sense of community that results when everyone is in the same room, but the quality of the activity was not diminished because of

the virtual environment. There was no social distancing and all students had the identical experience. Each activity session was recorded, so students could revisit other presentations, but more importantly could evaluate their own in a manner not available in the past.

Activity #2: Arches and Catenaries

Usual format: Three stations are set-up in the classroom comprised of a roman arch, flat arch, and cables. After an introductory presentation on funiculars and catenaries, the students are divided into three teams. Using chains and blocks, the students at each station construct an arch or cable structure and answer questions based on what is physically observed. Their answers to these questions determine their grade for the activity. After a round at each station, the students return to their seats for more detailed information that helps explain what was observed. The students take a second round through the stations with new questions and finish with concluding lecture material that discusses how these same principles work in three dimensions. Each student submits an activity sheet for grade at the end of the class period.

Figure 1: ARCE 106 student at two of the three testing stations in the activity on arches and catenaries

COVID format: Those students who could attend class followed the same format as in previous years as shown in Figure 1. Their experience was actually enhanced as team sizes were smaller which increased the participation of every student. Because students were gathered closer that six feet, social distance Category E (Table 1) was in effect while students were at the stations and was reduced to Category D during the lecture portions of the activity.

The original plan for the students participating virtually was to have a synchronous Zoom session for each activity section. Because this added substantial effort for the instructors with only marginal benefit for the students, the instructors conducted a synchronous Zoom session during the final activity period and those students with a schedule conflict could participate asynchronously by watching the Zoom session recording. The lecture portion of the activity was simultaneously delivered live to the students in class and virtually over Zoom to the students at home. The PowerPoint slides were screenshared with the students at home and the Zoom session

was projected on the classroom screen for those attending face-to-face. The instructor remained within the range of the camera in order to be seen and heard by all students.
For the time spent at the stations, the second instructor joined the Zoom session using a smart phone as the camera and followed one team through all three stations narrating key points as necessary. The remote instructor was "pinned" to the screen so everyone at home could see it. All other participants had to be muted to preserve the recording which greatly reduced their ability to interact or ask questions. Students at home completed the activity sheets as individuals and submitted them through Canvas at a prescribed due date that accommodated those students participating asynchronously. There were lessons learned regarding the need for auxiliary camera, wireless microphone, extended phone battery life, and the reduction of dead space in the Zoom recording. The students at home were able to complete the activity but the richness of their educational experience was clearly less.

Activity #3: Concrete Anchor Bolts

Usual format: For the three material modules (concrete/masonry, timber and steel), the lecture focuses on the material and the activity covers connections. For Activity #3, the student activity sections are divided into eight teams. Four teams start in the classroom where the instructor completes the concrete lecture from Tuesday and uses the Hilti technical literature to have the students determine the tensile pullout strength of a screw, mechanical and adhesive anchor bolt using specific examples. The other four teams proceed to the concrete lab where visiting Hilti engineers have the students drill and install mechanical and adhesive anchor bolts into concrete. They let students use other Hilti tools such as the powder-actuated nail driver. The teams then switch. Finally, the entire section participates together while the anchor bolts are tested to failure. The activity assignment is to compare the actual pullout strength with the predicted pullout strength and discuss why they might be different. Each team turns in the assignment sheet at the end of class.

Figure 2: ARCE 106 students executing a tensile pullout test on anchor bolts and drilling a hole into a concrete block to install an anchor bolt

COVID format: The Hilti engineers were not allowed on campus due to the pandemic but Hilti still donated the anchor bolts, adhesive and tools necessary to conduct this activity. The lecture portion of the activity was pre-recorded using PowerPoint show and uploaded to Canvas for all students to watch asynchronously. The face-to-face students met at the concrete lab at their scheduled section times and the instructor oversaw the students installing the anchor bolts into concrete and conducting the subsequent pullout tests as shown in Figure 2. The students recorded the data and departed. Because students were outdoors, the social distancing was Category B.

The first activity section was recorded using a video camera and a wireless microphone. The instructor edited the video using Screencast-O-Matic and posted it on Canvas. The students participating virtually watched the video and used the data on the video to complete the assignment. The assignment was completed individually rather than in teams and was submitted on Canvas by the due date.

The instructors felt that the learning experience for the face-to-face students was about the same as the usual format but without the benefit of meeting the Hilti engineers and using the additional tools they bring. The virtual students had to watch the activity rather than doing it themselves making them less engaged. The quality of the edited video was higher than that of a Zoom session but the students were not able to interact or ask questions. The production, editing and publishing of the video required a significant amount of instructor time and effort. The instructor held a special Zoom session after the last activity for those students attending virtually just to interact and answer student questions. Only a handful of students attended.

Activity #4: Timber Connections

Usual format: The entire activity is conducted in the indoor and outdoor portions of the high-bay lab. Simpson Strong-Tie representatives travel to campus and assist with the activity. Hayward lumber donates the timber pieces and Simpson Strong-Tie donates the connectors. The 24 students are divided into six teams of four students where each student team assembles various joist hangar connections and uplift (hurricane) ties. Various teams use nails driven with a hammer, nails driven with a pneumatic palm-nailer, or screws driven with a power drill to connect the hanger connectors to the lumber. The assembled connections are tested to failure on the universal testing machine. Students record the allowable load provided in the product literature, the ultimate load as tested, and the installation time for each connection on an activity sheet and analyze the cost versus benefit of the different connections. Each student submits an activity sheet at the end of the activity period for a grade.

COVID format: The Simpson Strong-Tie representatives were not allowed on campus due to the pandemic but still donated the materials and literature on the strength of the various hangers. The instructor oversaw the conduct of the exercise. The sequence of events and quality of the learning experience was identical for those students attending in person as shown in Figure 3. The virtual accommodation for those students unable to attend was an asynchronous video recording of one entire activity section. The instructor had a wireless microphone and the video was significantly edited with Screencast-O-Matic to provide a clear and efficient presentation. The virtual students used the data on the video to complete their graded activity sheet. All

activity sheets were submitted on Canvas and the assignments were completed individually rather than in teams for all students.

The quality of the experience was reduced for the virtual students because they watched the activity being completed rather than experiencing it themselves. The availability of the video allowed all students to pause, re-watch, and fast-forward through the material. During the testing of connections, the video camera was able to provide up-close views of the material as it was failing that students in class could not see as well. The construction of the connections was held outdoors, but the students within each team were sufficiently close that social distancing was Category B with the addition of face shields. Because the face shields were not rated properly as impact resistant protective eyewear in a shop setting, students had to don additional safety glasses and suffer through fogging of this eyewear caused by the limited air circulation within the face shield enclosure, making assembly somewhat difficult. For the testing of connections, it was Category C, thus no face shields were necessary at this phase.

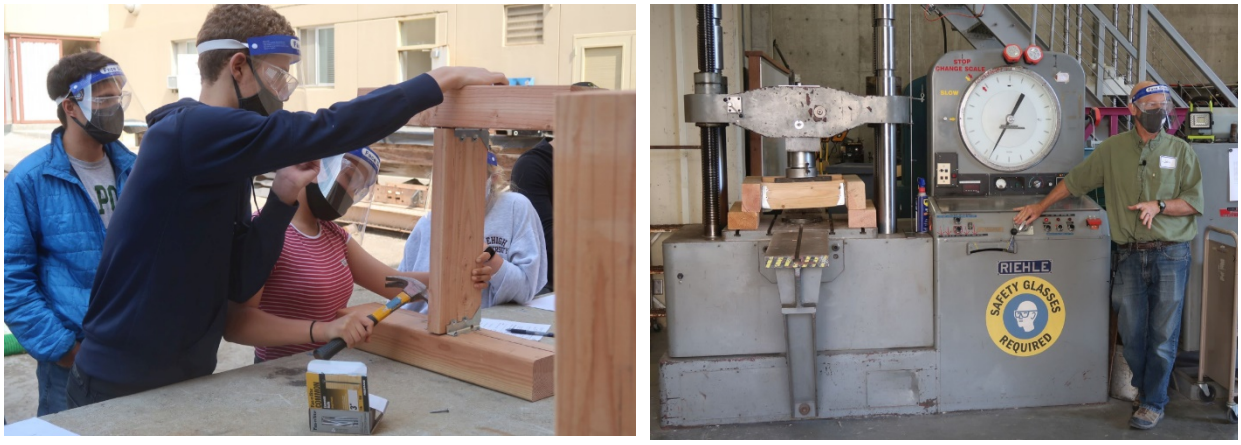

Figure 3: ARCE 106 students building and testing timber connections for Activity 4

Activity #5: Steel Connections

Usual format: The activity begins in the classroom where entire activity section is divided into eight teams of three students per team. The instructor provides an orientation, a laboratory safety briefing, and a brief lecture on the stress-strain curve for a ductile steel. Students are introduced to the material properties of the steel bars that they will soon be welding together. By defining failure as yielding of the steel, students learn that 36 ksi steel with a 2 inch by ¼ inch rectangular cross-section will fail at 18,000 pounds of force. Half of the teams were escorted to the welding shop while the other half were taken to two steel sculptures – the AISC Structural Steel Teaching Sculpture and a second sculpture completed as a past student senior project.

The welding shop provided instruction on welding and created four different types of specimens where two pieces of steel are connected: butt weld on one-side, butt weld on both sides, split groove weld one-side and split groove weld both sides. Under the close supervision of the shop manager, each student welds a bead on a specimen. The other teams study the steel sculptures and answer questions about the different connections and configurations of steel shapes they

encounter. The exercise reinforces content from the lecture and students are using their Building Construction Illustrated textbook to assist. At the halfway point, the teams switch and go to the other station.

Finally, the entire activity section gathers at the Universal Testing Machine to conduct a tensile test on the welded specimens where they are loaded to fracture. Students recognize when yielding occurs and discuss the quality of a weld based on where and at what load the specimen fails. They compare the performance of the four types of specimens. Each team turns in their activity sheet at the end of the class period.

COVID format: For those students who attend face-to-face, the exercise is conducted exactly as described above and students have the same rich hands-on experience as shown in Figure 4. The social distancing protocols were Category D for the classroom portion, Category B for the steel sculptures, Category C for the specimen testing and Category E for the welding.

The virtual alternative for this activity is asynchronous. One activity team is recorded in the welding shop and testing of samples for one activity section is record in the high-bay lab. Both videos are edited in Screencast-O-Matic to enhance content and add features to increase clarity. The instructor created a narrated video of the steel sculptures to repeat the questions and clearly show what joint or connection is the subject of each question. A recorded PowerPoint show is used to present the safety briefing and stress-strain curve content. The quality of the experience was less rich for those students who had to watch rather than do…. especially for the welding exercise.

Figure 4: ARCE 106 students welding steel and examining steel connections in Activity 5

Because working in teams and developing a community is an important goal of the course, the virtual students were divided into teams for this assignment as well. The virtual teams were identified in advance based on the record of student attendance in prior activity sections. Student teams were provided with the emails of their members and tasked to meet on their own. Each team was required to submit one joint assignment. This proved difficult because each week different students were going on and coming off of quarantine. Those freshmen who chose not to remain at home were required to live on campus and entire floors were quarantined when a single student tested positive. The assignment of teams became highly fluid. Some students ignored their team assignment and did the assignment by themselves for which they were

penalized. For many teams, however; the effort was effective and the collaboration of thought provided better answers to the questions. The instructor held a special Zoom session after the last activity for those students attending virtually solely to interact and answer student questions.

Activity #6: Digitally Fabricated Trusses

Usual format: The students are divided into four teams of six students. Each team is provided one 16" x 32" piece of 0.12" thick wood laminate Lauan Board. Each team makes a 30-minute on-line reservation at the digital fabrication (D-FAB) laboratory outside of normal classroom hours and downloads *Laser cutting File.3dm*, a three-dimensional CAD file using Rhinoceros software onto a flash drive. With the assistance of shop personnel, teams use this file to laser cut the individual pieces of a truss. Students bring their wooden truss pieces to the normally scheduled activity class. Each team is provided with plastic connectors and tools to assemble a three-dimensional two-plane Warren truss bridge.

The instructor presents a lecture on trusses that defines what they are, tells why and how they are used, and shows real world examples. Each team weighs their assembled truss bridges. Each truss bridge is tested to failure by hanging an empty bucket from the midspan and progressively filling the bucket with sand until the bridge collapses. Each team computes the strength-to-weight ratio as a key metric, comments on the advantages of trusses and observes that the failure came violently and without warning. Eventually a statistical analysis of the data from the identical trussed bridges of all class sections is presented and a discussion of what allowable load should be prescribed by a truss manufacturer to attain a specific probability of failure. Students submit the activity sheet at the end of class. Other items included in this activity were Learning Styles feedback, a K'nexercise introduction and a scheduling exercise to project their course enrollments to graduation.

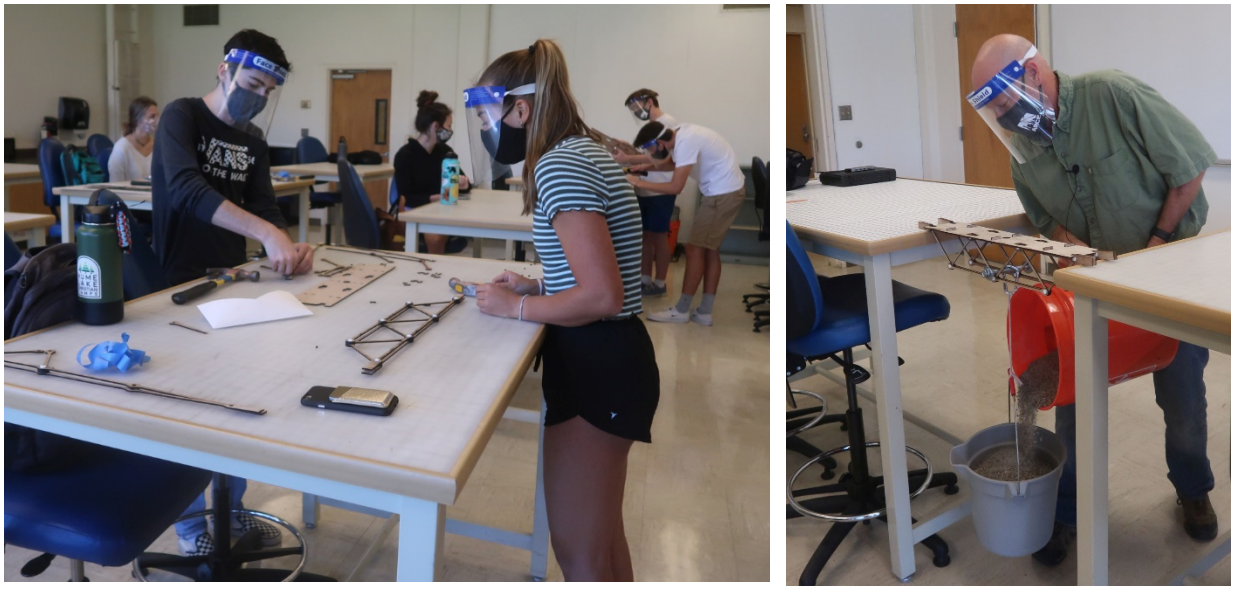

Figure 5: ARCE 106 students assemble and test truss structures from materials that they laser-cut in the digital fabrication laboratory in Activity 6

COVID format: To minimize unchecked COVID transmission, the college only allowed students to use classroom and laboratory facilities during scheduled class hours with an instructor present. As such, students were not able to independently go to the Digital Fabrication Lab in advance to cut their truss pieces. Instead, the instructor formed student teams based on who historically came to the face-to-face class and brought all teams to the D-FAB lab as part of the activity. Because the lab was otherwise closed, the instructor enlisted the lab technicians to assist and used all four laser printers available in the lab to get the truss pieces cut during class time. Afterward, the face-to-face students constructed the two planar trusses, assembled them into a three-dimensional bridge, and tested them as shown in Figure 5. The pace was accelerated and other parts of this activity listed above were not conducted to make room for the trip to the D-FAB lab. Social distance Category E was used for the classroom and Category D for the D-FAB lab.

The virtual accommodation for this activity was an asynchronous edited video of one activity section. Students participating virtually downloaded the activity sheet from Canvas, watched the video which focused on one team's progress, completed the assignment as individuals, and submitted it on Canvas by the due date. The video provided a good tour of the D-FAB lab but lacked the richness of actually working the controls on the laser cutter. The students participating virtually had to watch instead of do and were not able to interact and ask questions. They were not able to participate as part of a team.

Activity #7: Slopes and Drainage Patterns

Usual format: The students attend classroom instruction on drainage patterns, computation of slopes, site plans, and an introduction to handicap ramps complying with the American Disabilities Act (ADA) using PowerPoint slides. The class is then divided into eight teams of three students each. The student activity sheet has a map of nearby Dexter Lawn open space and adjacent buildings. The teams capture the flow of water on that map and identify the various catch-basins into which the water flows. Each team is given a four-foot level and a tape measure and asked to identify and measure the steepest drainage slope on the map. There are several handicap ramps on the map. Student teams measure the slope of one ramp and report whether the slope meets ADA requirements. Students submit activity sheets individually at the end of the activity.

In preparation for the next activity on failure case studies, time is devoted to reviewing two sample failure case studies: the windows in Boston's John Hancock Building and the collapse of Washington State's I-5 Skagit River Bridge to illustrate the type of analysis required by the students. Students are divided into eight teams of three for this upcoming assignment.

COVID format: Figure 6 shows the students attending the activity face-to-face following the same procedure and performing the same tasks described above. The social distancing protocol for the classroom is Category C and for the outdoor slope and drainage exercise is Category B. The virtual accommodation for students who cannot attend is asynchronous. The lecture portion is recorded as a video which students can access on Canvas. The students attending virtually have a slightly different drainage exercise. They are asked to sketch a site plan for the land where they currently reside. They use arrows to show the flow of water away

from the property and label any curbs, drains or catch-basins into which the water flows. They identify where they think the steepest slope occurs, and document it with a photograph. The exercise is completed individually and submitted over Canvas by the due date. While students are not able to interact and ask questions, they are able to do the activity, rather than watching others. For the upcoming failure case study activity, the instructor was able to assign teams and prepare the students for the next activity because it will be virtual and synchronous for all students.

Figure 6: ARCE 106 students measure slopes and analyze drainage patterns in Activity 7

Activity #8: Failure Case Study Presentations

Usual format: In teams of three, the students investigate a failure case study prior to class and the activity is used for group presentations of their findings. Given a series of library and web-based resources, student teams select a building failure case study and create a four-minute PowerPoint presentation which answers the questions: Which building system type failed? Which key components of the system were involved and how did they fail? Who suffered from this event? Which profession(s) was involved with the cause? What could have been done differently to have prevented the situation? Each student in the team has to participate in the presentation. The student teams also submit a written report which provides an introduction; a paragraph for each of the questions posed above; paragraphs to separately address the global, cultural, societal, environmental, and economic issues; and a conclusion. This assignment provides embedded indicators used for assessing the attainment of several ABET student outcomes. Students meet in the classroom and each team makes an oral presentation in turn.

COVID format: Because the entire activity is virtual, it is similar to Activity #1 with a synchronous Zoom session for each activity section. The only additional challenge is that teams had to meet virtually to prepare the presentation. They had to coordinate the screen sharing and the role each member plays when they are presenting from different locations. The experience for every student was comparable to being in the classroom. All of the advantages and disadvantages discussed for Activity #1 apply here as well. No social distancing was needed.

Activity #9: Electrical Circuits

Usual format: Students are divided into six teams of four when they arrive in class where there are six stations set up on tables in the classroom. Each station consists of a half sheet of plywood backed by vertical wooden studs simulating a portion of a timber framed wall, a bucket of components, and necessary tools such as wire strippers, various screw drivers, and pliers. Each station has a different electrical circuit configuration featuring such things as a main panel box, a doorbell, a three-way switch on a light, a dimmer switch, a motion sensor, and/or a switched outlet. Following an orientation and safety briefing, each team is given an activity sheet with a series of questions for the team to answer. The six teams proceed to their respective stations and using the wiring diagram for that station, attempt to construct it correctly. As each team finishes, the instructor inspects their work and connects power to verify it works properly. Once all teams are finished and each station is successfully tested, the instructor uses the outlets on each station to connect the six stations in series representing a single circuit coming from a main panel box. The teams do not rotate through the other stations, but the students assisted by the instructor, present the answers to the activity sheet questions that apply to their station to the rest of the class. Students learn first-hand how hard it can be to bend and attach 12- or 14-gauge wire to electrical outlets, to fit multiple wires inside a junction box, and make a secure connection using wire nuts.

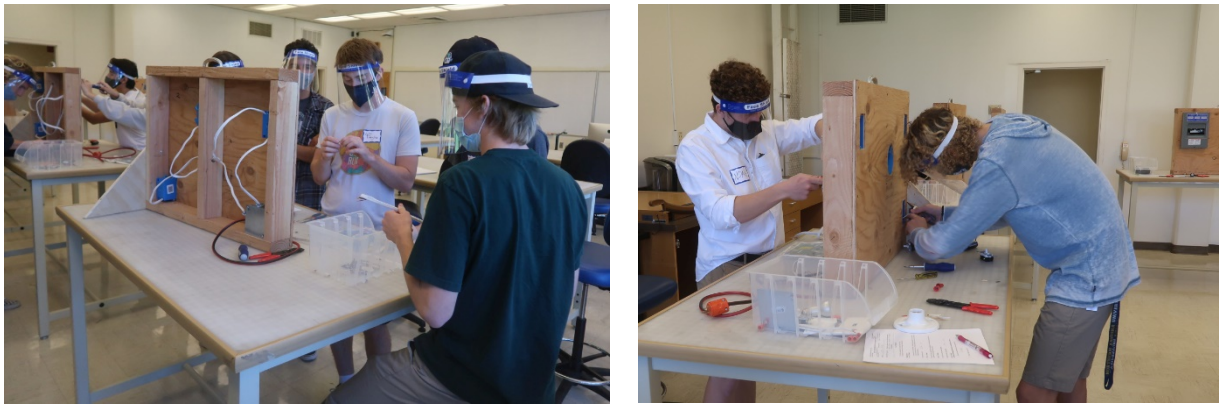

Figure 7: ARCE 106 students wire various electrical circuits in Activity 9

COVID format: For the students who attend the class face-to-face, the process is identical as shown in Figure 7. Students are divided into teams that allow as many of the stations to be completed as possible. For the activity class sections this quarter, between two and five of the stations were used based on the number of students who were able to attend. The students missed seeing all six stations wired together. The instructor summarized the unwired stations for the class. Because the students were gathered closely around each station, the social distancing protocol was Category E where students were in face shields as well as masks.

Similar to Activity #2, the virtual accommodation consisted of one synchronous Zoom session for those who could attend and the asynchronous recording of the Zoom session for those who could not. The Zoom session was projected on the screen in the classroom and the instructor remained in front of the computer camera during the introductory portion. While the student teams were wiring the various circuits, the instructor joined the Zoom session with a smart phone and went from station to station narrating what was occurring to the students at home and

coaching those students in class on wiring the circuits as well. The virtual students were able to answer the activity sheet questions based on the answers provided after the circuits were linked together. While the face-to-face students were taking the stations apart and returning them to the original condition, the instructor was able to conduct a personalized session with the students participating virtually to ensure all of their questions got answered and they fully understood the activity. As with many of the other activities, those students who watched instead of doing did not have as rich an experience.

Activity #10: Design, Bid, Build through the K'nexercise

Usual format: The K'nexercise [7], [8] is a role-playing exercise that uses K'nex toys to illustrate the design-bid-build project delivery method and the motivations of the players in it. The students receive an introductory explanation of the exercise in Activity #6 and state their preferences towards being an architect/engineer, project manager, or contractor. In Activity #7, the architect/engineers are given design specifications for a project and they are given a week to produce a complete design with drawings and a cost estimate for materials, labor, and profit. The project managers are given those plans in Activity #8. The project managers brief the owners, review the plans, have the architects make any necessary changes, and approve the final plans within a week. In Activity #9, the contractors are given the final plans and a week to prepare a formal bid on the project. The work culminates in Activity #10 where after a bid opening ceremony, the contractors build the project for time which produces an actual cost for the project. The projects are inspected and load tested. Based on the rules of the game, every team receives a grade and the final results are presented prior to the final exam. The rules are designed to give the students the same motivations as their counterparts on a real project. The K'nexercise is the culminating event in the course and tends to be loud, raucous, competitive and fun.

Figure 8: ARCE 106 students participate in a modified version of the K'nexercise to learn about the design-bid-build project delivery method in Activity 10

COVID format: During this pandemic, the college and university resources are closed to students except during in-class hours for the face-to-face courses. The success of the K'nexercise

is largely due to the students having access to the 44,000 K'nex rods and connectors in the department labs outside of class. As a result, the K'nexercise was reduced to a single week activity for this group. The rules were modified and all students played the role of contractors. Student designs and plans from a previous year were used as the approved designs. The new rules were posted on Canvas and students arrived for the activity without ever having seen the project plans.

The virtual accommodation was a synchronous Zoom session for each activity. There was no asynchronous alternative. The face-to-face students were divided into teams of two to four students depending on how many came to class. The students participating virtually were randomly divided into teams and assigned to breakout rooms. Both the virtual and face-to-face students were given the first hour to analyze the plans, do a material take-off, estimate the construction time and submit a bid. The face-to-face students submitted their bids in a sealed envelope and the virtual students submitted their bids on Canvas. The face-to-face students picked up their materials from the K'nex "warehouse", laid their pieces out carefully and constructed the project according to the plans as quickly as possible. The instructor signed into the Zoom session using a smart phone as a camera and narrated the progress of construction for the students participating virtually. The projects were completed, inspected and load tested as shown in Figure 8. Social distancing was Category E because students were closer than six-feet during both the bidding and building process.

The exercise results were tabulated after the class ended and were presented to students at the final lecture on Ethics and Professional Responsibility. The virtual student team results were scored based on their material estimate and time of construction using the average time of those projects actually constructed during class. Each activity section was given a different design, so there was no benefit from sharing of information with earlier sections. While the face-to-face students cleaned up and returned the K'nex pieces to the warehouse, the instructor conducted a question and answer session with the students participating virtually. The students at home missed out on the fun of actually building the structure but were still able to participate in the competition and receive a score in the game. While the K'nexercise was fun, the learning value of experiencing the design-bid-build delivery system was diminished for all students with this shortened version where all students were contractors.

Midterm and Final Examinations

Usual format: ARCE 106 includes both a midterm and final exam normally conducted in the same large room where the lectures occur. Students are separated to the extent possible. Both exams are open book and paper exam copies are distributed and collected in class. A portion of the room was designated for those students who purchased the electronic textbook to use their computers. Both instructors monitor the exam. The exam questions were predominately short answer, matching, and multiple choice.

COVID format: During the pandemic, both exams were conducted in a virtual environment using the testing capabilities of Canvas. The instructors faced the same academic integrity issues faced by all courses in this environment. Students were required to keep their cameras on during the exam in the Zoom session and both instructors were monitoring. The

instructors were challenged to create questions that fit the capabilities of the Canvas software. The advantage was that the software graded the exam. There was a disincentive to use short answer questions that needed to be graded separately but are needed to assess higher cognitive capabilities. Canvas has ability to randomize the order of questions within the exam and the order of responses within a question. When students needed to speak with an instructor during the exam, they were able to use the private chat feature within Zoom, and all Zoom chats are archived for later review.

Ultimately, the questions on both the midterm and final exams were similar in scope, level of difficulty and format as those given in past years. The academic performance by the students in this pandemic-induced environment was similar to past year performance with exam averages consistently falling in the 77 to 83 percent range.

Assessment Data

Course Objectives

Students were surveyed at the end of the course in Fall 2015, 2016, 2017 and 2020 for their assessment of the degree to which they have individually attained the six course objectives. They responded according to the following Likert scale rubric:

5 = Very confident that I have met the objective
4 = Somewhat confident that I have met the objective
3 = Not sure
2 = Somewhat confident that I have not met the objective
1 = Very confident that I have not met the objective

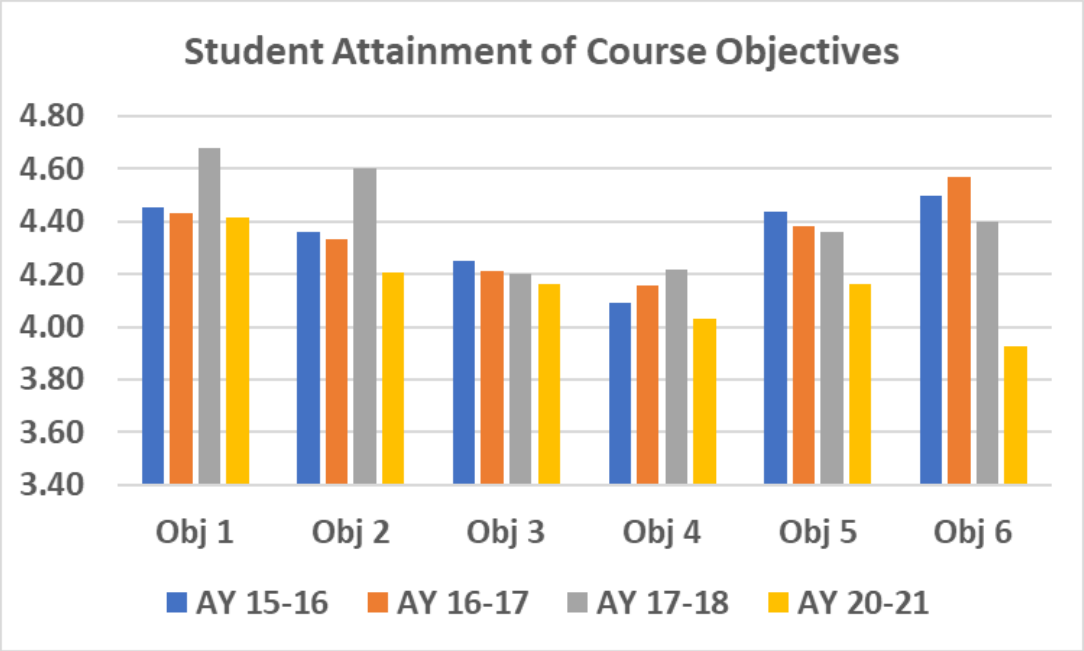

Figure 9: Results of student surveys assessing the attainment of the course objectives for ARCE 106 for various years.

- Objective 1: Identify and illustrate building systems in our day-to-day lives and explain the functions they serve.
- Objective 2: Articulate the key components of different building systems with their role towards a successful building in an architectural engineering context.
- Objective 3: Describe how specific buildings integrate various building systems together successfully.
- Objective 4: Compare/Contrast when to use different structural systems and different structural materials under various scenarios.
- Objective 5: Describe the roles/responsibilities of the various professions involved in the creation of a building.
- Objective 6: Develop a sense of community with your fellow ARCE students.

The number of students participating in the survey in 2015, 2016, 2017, and 2020 was 64, 82, 83, and 65, respectively. Compared to previous years, Figure 9 shows that the students in Fall 2020 felt only slightly less confident that they met course objectives 1 and 3 than previous freshman classes. This is not surprising since there was little difference in the way the lecture material was presented. The homework and exams were also very similar to past years and exam performance was roughly the same. Students felt a bit less confident with respect to objectives 2, 4 and 5. The results of Objective 5 seem reasonable because that objective is largely met through the K'nexercise which was reduced in scope for the Fall 2020 class. The confidence in attaining Objective 6 was much less. This is clearly due to the virtual accommodation in the activities and lack of human interaction in the Zoom lectures. The instructors also found that it was much more difficult to learn the student names in this environment.

Assessment of Activities

An assessment of the activities needs to separate those students who took the activity face-to-face from those who participated virtually. Figure 10 shows the number of students in each mode for all ten activities based on the end-of-course survey. There were 82 students in the course but only 65 students completed the survey. The incentive for completing the survey was 5 bonus points on the final exam which boosted the response rate to 79%.

Activities 1 and 8 were entirely virtual by design. There was about a 50-50 split between the number of students attending in Activities 2 through 7. There was a slight fluctuation as students came on and off of quarantine. There was a substantial drop in students attending face-to-face for Activities 9 and 10 as entire floors of the dorms were quarantined, particularly after Halloween.

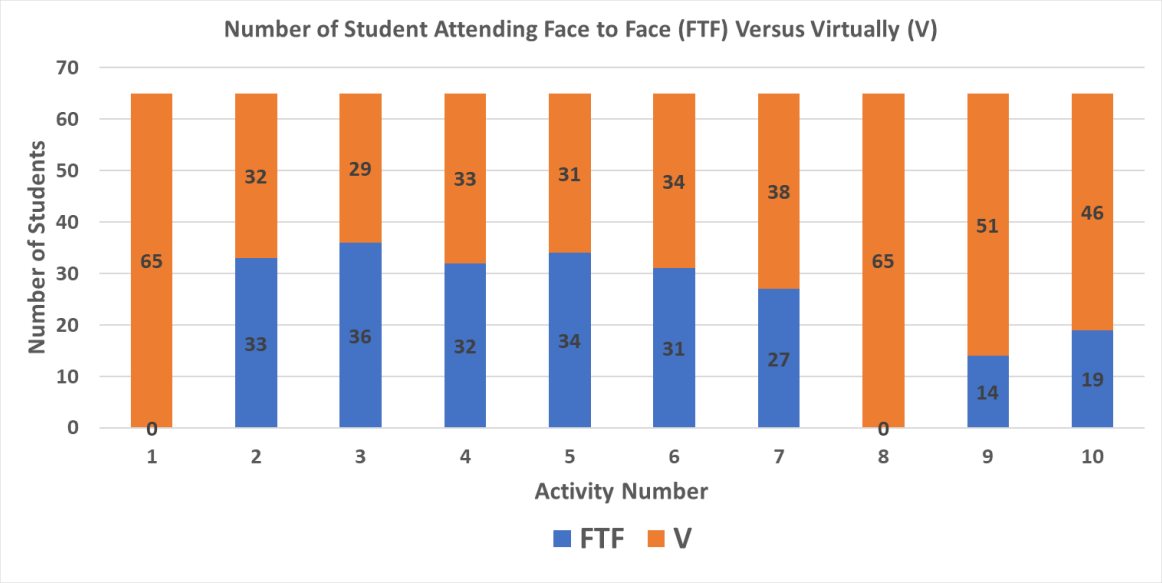

Figure 10: The number of students attending ARCE 106 activities in the face to face versus virtual mode in Fall 2020.

The students have been surveyed each year since the course began on the quality of the ten activities. For each activity, students provided a Likert scale rating using the following rubric:

5 = I really enjoyed and got a lot out of this activity.
4 = I sort of enjoyed the activity and got something out of it
3 = Neutral, I neither liked nor dislike the activity and got marginal benefit
2 = I sort of disliked the activity and got little from it
1 = I disliked this activity, or thought it was a waste of time.

Figure 11 shows the student ratings for each activity since Fall 2015. The survey was administered in class from Fall 2015 to Fall 2019, so the response rate was 100%. The survey in Fall 2020 as previously mentioned had a response rate of 79%. As such, the number of students participating in the survey in Fall 2015, 2016, 2017, 2018, 2019, and 2020 was 64, 82, 83, 95, 94, and 65, respectively. For Fall 2020, the data were divided into those attending face-to-face versus virtually. Those student numbers were different for each activity.

The Fall 2020 ratings were similar to previous years for Activities 1 and 8 which were entirely virtual given the nature of the activity. The ratings by those students participating virtually were significantly lower for activities 2 through 6, 9 and 10 which had a significant hands-on, face-to-face component where the virtual students only watched and in some cases were unable to ask questions and interact. The biggest surprise was the highly favorable rating on Activity 7 where the students at home were analyzing their individual drainage patterns. Comparing with past years, those attending face-to-face and virtually this year gave this activity the highest rating it has ever had. That can either be attributed to either a small sample size or perhaps the students were so grateful to have a face-to-face experience on campus or a hands-on experience at home that they enjoyed it more than usual. For those living on campus, ARCE 106 was the only face-to-face class these students had in the first quarter of their freshman year, and this may explain the higher than normal ratings for the face-to-face activities when compared with past years.

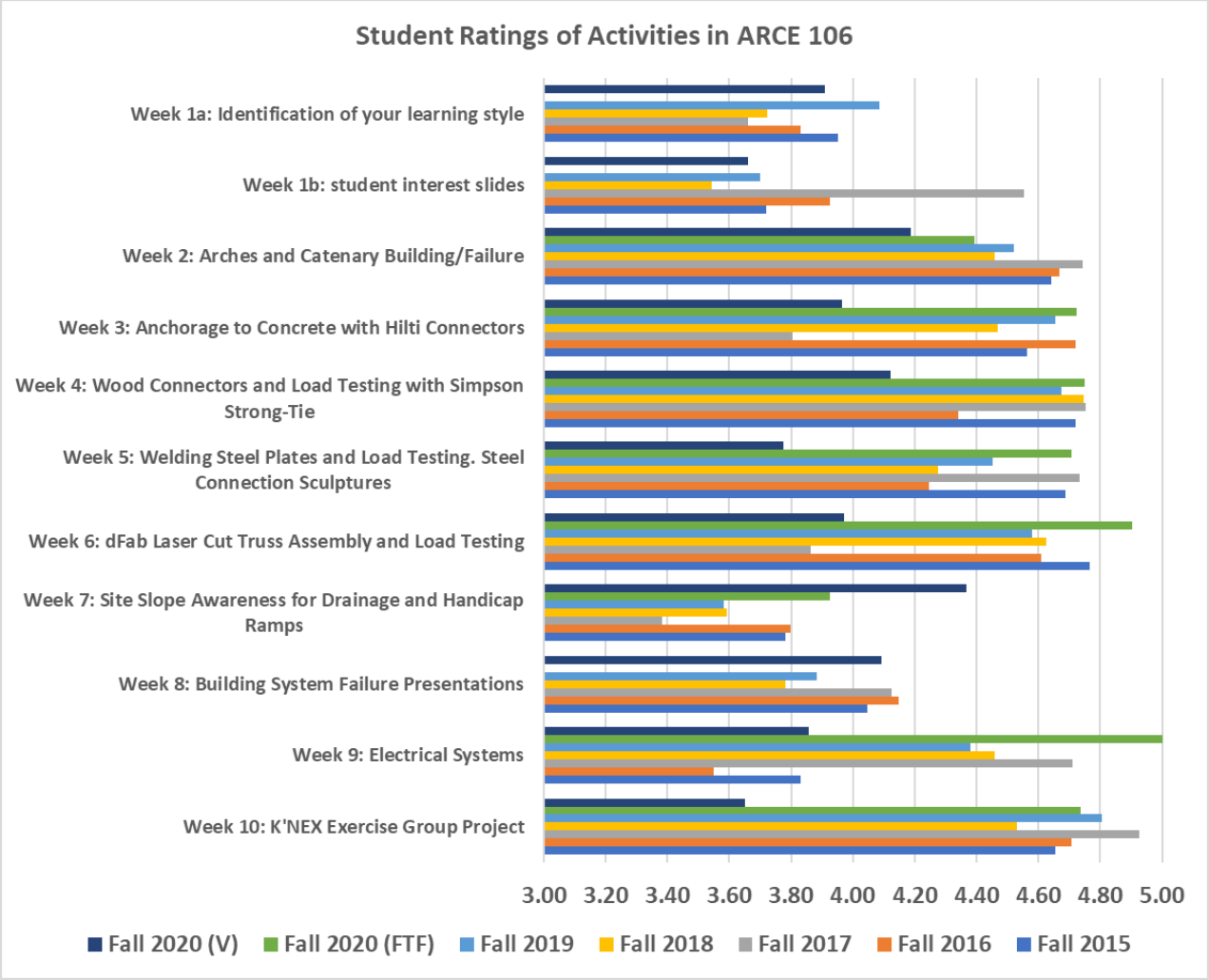

Figure 11: Student ratings for each ARCE 106 activity since Fall 2015

Both instructors applied their own ratings of the activities in Fall 2020 using the following Likert scale rubric.

5: No difference in quality of experience from previous years. In fact, the solution this year might have provided a better instructional experience for the students

4: Little difference in quality of experience. The difference could be due to a reduction in the activity itself or the degree of interaction between the students

3: Medium difference in quality of experience. The difference could be due to a substantial reduction in the activity or the low quality of the virtual materials or the significant reduction in student/instructor interaction or having to watch rather than do an activity

2: Significant difference in quality of activity. A major portion of the activity was not available due to the constraints of the pandemic

1: Activity was a failure. Students were not able to meet the objectives of the activity due to constraints of the pandemic. This activity needs to be restructure for the future

Table 2: Instructor assessments of the student experiences in both the virtual and face-to-face activities for ARCE 106 in Fall 2020

Activity Number	Instructor #1		Instructor #2	
	F2F	V	F2F	V
1a: Learning Styles	N/A	5	N/A	4
1b: Student Presentations	N/A	5	N/A	5
2: Arches and Catenaries	5	3	5	3
3: Anchor Bolts	4	3	4	2
4: Timber Connections	4	3	4	2
5: Welding Steel	5	2	5	2
6: Truss Fabrication	4	2	4	3
7: Site Slope and Drainage	5	4	5	4
8: Failure Case Studies	N/A	5	N/A	4
9: Electric Circuits	4	2.5	3	2
10: K'nexercise	3	2	2	2

Table 2 shows the instructor assessment for both the face-to-face and virtual versions of each activity. The separate instructor ratings agree with no individual rating varying from the other by more than 1. There also appears to be no correlation between the ratings and which instructor taught that module. For many of the activities, there was a significant loss in quality of experience for those students who participated virtually.

Preferred Modes of Instruction

At the mid-point of the course after several virtual accommodation methods had been tried, the instructors asked those students who had participated virtually for input. Using a poll question in Zoom, the following question was asked:

Which statement with respect to virtual activities in ARCE 106 most resonates with you as the most important. (Pick one)

- I want synchronous activities during my assigned activity session
- I want at least one synchronous activity session with an asynchronous option for viewing later
- I want asynchronous activity sessions with well edited videos
- I want asynchronous activity sessions with a synchronous Q&A session
- I want the instructor to choose the asynchronous/synchronous mode that best fits the specific activity

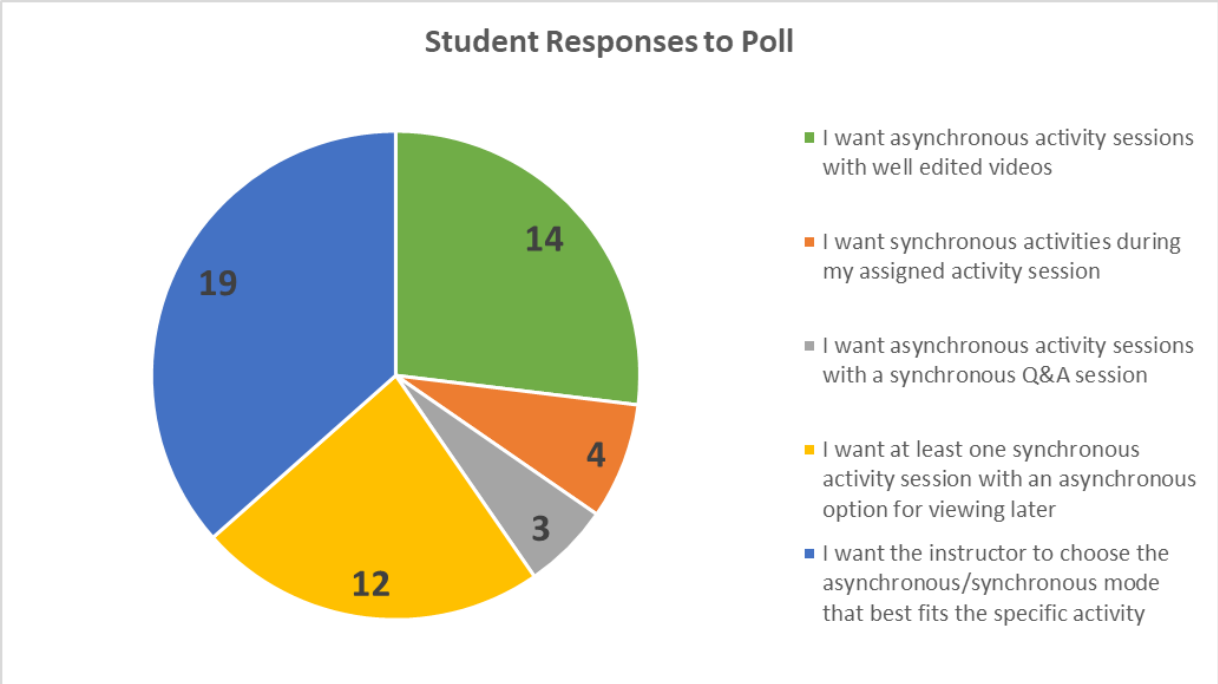

Figure 12: Results of a student poll asking ARCE 106 students for priorities regarding virtual accommodation in the course.

Fifty-two students (63% of the course) responded and Figure 12 shows the results of the poll. The student responses indicated the preference for a well-crafted asynchronous experience over the synchronous experience for the activities. The written comments in the course survey repeatedly stated that having at least one synchronous activity session with an asynchronous back-up option was preferred. The most popular response was to trust the instructor to make the virtual accommodation decision based on the content and circumstances of the activity.

Instructor Evaluations

A final assessment data point for this experience are the university student evaluations of the performance of the instructors. The same two instructors have taught all six iterations of this course, so a comparison of past ratings with the Fall 2020 iteration may provide some insights when combined with the free-form written comments.

The faculty in every course at Cal Poly receive a composite score for instructor performance based on the student responses to questions on being well-prepared, knowledgeable on the material, and good communicators, as well as on overall teaching ability. The statements are phrased in a positive manner and students make a rating from 1 to 5 based on a rubric of 1= Strongly disagree, 2= Disagree, 3= Neither Agree nor Disagree, 4= Agree, and 5= Strongly Agree. The ratings for both instructors since Fall 2016 are shown in Table 3.

Table 3: Student ratings for ARCE 106 instructors based on instructor performance

	Fall 2016	Fall 2017	Fall 2018	Fall 2019	Fall 2020
Instructor #1	4.90	4.96	4.95	4.95	4.89
Instructor #2	4.89	4.93	4.95	4.92	4.87

Students were also asked the question using the same format, scale and rubric for "I feel the course was educationally effective". The student responses are in Table 4.

Table 4: Student ratings for both instructors in ARCE 106 based on whether the course was educationally effective

	Fall 2016	Fall 2017	Fall 2018	Fall 2019	Fall 2020
Instructor #1	4.80	4.81	4.81	4.88	4.78
Instructor #2	4.79	4.80	4.81	4.85	4.78

In both cases, the students rated the instructors and the course very highly with a negligible difference between the years. The written student comments reinforced that the virtual accommodations for the face-to-face activities were of lower quality than what those attending face-to-face received. Several student comments expressed gratitude for a face-to-face experience and an opportunity to use the university lab facilities. Some students also stated that they understood the restrictions forced by the pandemic and felt the instructors did the best they could under the circumstances. If the same virtual accommodations had been offered in a non-pandemic situation, the students would have probably been less generous.

Conclusions

The ARCE 106 experience in the Fall 2020 quarter illustrates that it is possible to conduct a course that has an intense laboratory or activity component face-to-face in a safe manner and provide an alternative virtual experience for those students who either cannot attend or do not feel safe attending. It requires appropriate social distancing protocols suitable to the circumstances and location of the face-to-face exercises. For the students who attend in this manner, the experience is of the same quality and educational value as that conducted under non-pandemic conditions.

The quality of the virtual accommodation varies greatly depending on the type of activity being replicated. There are a number of options involving synchronous Zoom sessions, asynchronous videos, and conversions of the entire activity to a virtual format. It requires a lot of extra work for the instructor but the best virtual option can be applied to the situation encountered. As the results in the paper show, the quality can vary but it is possible for those students attending virtually to participate in the activities to some extent, complete all of the course requirements, and meet the course objectives to a large degree.

The virtual experience can work seamlessly for large enrollment lecture courses where the students are already largely passive and there is little interaction with the instructors. In fact, the virtual experience can be better because it is recorded and can be viewed later by students who did not absorb all of the material during class either because they got distracted, the pace was too fast, or they were not able to attend. The virtual experience is a less acceptable substitute when the class sizes are small, student-faculty interaction is a key part of the course, and the students are engaged in hands-on activities that require supplies, equipment or close supervision. It is also harder to conduct a lab or activity as a member of a team in the virtual environment. The challenge is magnified if the instructors do not know who is participating face-to-face or

virtually on any given week and thus cannot form groups in advance nor have them do any preparatory work prior to the start of class.

Nevertheless, it can be done to some extent in times of emergency as demonstrated here. Hopefully, as the pandemic ends, we can adopt some of the greatest benefits of the virtual environment to enhance the educational experience for students. Also, faculty will hopefully not be forced to accept the less desirable attributes of virtual education to reduce budgets and improve efficiency at the expense of time-tested pedagogical practices.

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